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DEMONSTRATION TEST OF INWOODS PULP CHIP PRODUCTION IN THE FOUR CORNERS REGION

George R. Sampson, Harold E. Worth, and Dennis M. Donnelly

FOUR CORNERS REGIONAL COMMISSION

Abstract

Pulpwood and nonmerchantable material were chipped in the woods by a portable debarker-chipper. Two test areas were harvested: a ponderosa pine site in Arizona and a spruce-fir site in Colorado. At the pine site, both saw logs and pulpwood were harvested; saw logs were trucked to a sawmill, but sawtimber tops and pulpwood trees were debarked and chipped in the woods. Harvesting at the spruce-fir site was a thinning of pulpwood-size material following a sawtimber harvest. Sound dead timber was chipped along with thinnings. Chips from both areas were delivered to a pulpmill at Snowflake, Arizona. Feasibility analysis included physical, economic, and environmental evaluation of the inwoods debarking-chipping system as compared with conventional roundwood harvesting.

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Demonstration Test of Inwoods Pulp Chip Production in the Four Corners Region

by

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FOREWORD

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SUMMARY AND CONCLUSIONS

During the summer of 1973, Southwest Forest Industries, Inc., cooperated with the Forest Service, USDA, in a study of inwoods production of pulp chips. The purpose was to find a feasible means of producing pulp chips from small trees and from residues ordinarily left in the woods after harvest. In this demonstration test, partially funded by the Four Corners Regional Commission and involving several other participants, a Nicholson Logger Model Utilizer debarked and chipped pulpwood, commercial thinnings, and associated nonmerchantable timber (fig. 1). Other harvesting functions were performed using conventional falling and ground skidding practices. Chips were transported from the forest chipping sites to the pulp mill or reload stations by highway-type chip vans.

The inwoods demonstration tests were conducted at two locations — one in ponderosa pine timber near Springerville, Arizona, on the Apache National Forest where pulpwood trees and sawtimber tops were chipped, the other in the spruce-fir type near Rico, Colorado, on the San Juan National Forest where thinnings and standing and down dead timber were chipped. The study spanned 63 working days from mid-June to mid-September, during which approximately 1,140 tons of pulp chips (bone-dry basis) were produced.

Operating conditions, times required for each harvesting function, delays and their causes, and production data were subsequently analyzed to estimate productivity and unit costs. Comparisons were made between this system and conventional means of producing pulp chips.

Conclusions reached include the following:

1. Demonstrations in Arizona and Colorado showed that the system works.

Formal demonstrations arranged on each of the test areas proved that there is considerable local interest in inwoods production of pulp chips. About 130 representatives of industry, public agencies, the press, universities, and the general public went to considerable trouble to get to the remote test areas for the demonstrations. While prospective entrepreneurs that observed the operation were not immediately convinced of its local applicability, most are actively interested in the system and have reserved judgment until the results of this analysis are available.

2. No major physical limitations were found.

The pulp chips produced were of high quality. Physical limitations of the system center around operating efficiency and the resultant costs. The system required more log handling than expected, and more than is needed in conventional harvesting. Also, the debarker-chipper was inoperable due to breakdowns an inordinately high proportion of the time. Some of this was attributable to power plant problems associated with high altitude operation. Design changes to correct power problems and the avoidance of jamups would likely remedy much of this limitation.

Fig. 1. — The Nicholson Logger Model Utilizer in action.

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Moving and positioning the debarker-chipper and chip vans on roads and terrain typical of conventional harvesting conditions did not pose any insoluble physical limitations. However, the debarker-chipper and chip vans are somewhat more sensitive to adverse weather which results in unfavorable ground and road conditions than are conventional log loading and hauling equipment.

3. Economic feasibility depends on operating efficiency.

Unit costs of producing chips were substantially higher with this system of inwoods chipping, as it actually performed in these tests, than for conventional means of production. If the productivity of the debarker-chipper unit could be improved for Southwestern altitude, weather, and road conditions through design changes and increased operating efficiency, unit costs could possibly be reduced sufficiently to compare favorably with conventional alternatives. Improvements required would include increasing the time in actual production of chips to approach 80 percent of the available operating time, and substantially reducing chipper moving time. This level of productivity appears to be within reach if the machine can be successfully redesigned for reliable high altitude operation and better maneuverability. It would also be necessary for the crew to become better organized and more expert in operating the system.

Although chip production costs are high, opportunities for reduction are apparent if mechanical and logistic difficulties experienced in this short-term test could be resolved in an ongoing operation. It is also apparent that the costs of obtaining chips from other sources are rising as a lesser proportion of the demand can be supplied from mill residues and pulpwood locations nearer the pulp mill. Comparison of inwoods chip production costs with present chip costs may therefore not be appropriate for future operations.

Timber utilization was improved over conventional logging as a result of inwoods chipping. This improvement was much greater in the spruce-fir type than in ponderosa pine. However, most of this same improvement is already being attained in some operations through removal of nonmerchantable timber in conjunction with regular timber harvests. While this latter approach would tend to result in somewhat lower total volumes removed than inwoods chipping, due to the high cost of hauling and handling cull material, it offers an opportunity to make better product sorts of both merchantable and nonmerchantable material at a mill yard and therefore can yield higher product values.

4. A substantial log deck is required.

The scope of this test did not permit evaluation of all possible operating modes. It was therefore necessary to subjectively select which modes would be tested, and then to project from the data obtained any variation in performance from the modes tested.

Conventional falling and skidding systems were found to integrate well with inwoods chipping, but considerable reskidding was required to build deck sizes up to practicable levels for each setting of the debarker-chipper. Any changes to improve the efficiency of these functions would be based on the same considerations as for regular pulpwood or sawtimber harvests.

Bucking practices were adjusted as needed to provide chippable material plus any other products to be harvested. For multiproduct areas, saw log tops were bucked off at the stump but were skidded and decked along with saw logs and pulpwood. Tops were limbed predominantly at the stump, with some cleanup at the landing. Log bucking and sorting under these conditions present the same problems as in conventional logging, and it is to be expected that some merchantable saw logs will end up being chipped. Most pulpwood-size material and chippable cull were limbed at the stump and skidded full length. To obtain the greatest efficiency in chipping it is important to leave logs and pieces as long as possible. Only when the log has severe crook is it desirable to buck it into a shorter length. It is also occasionally desirable to buck off a butt swell on a piece that would otherwise be too large for the debarker.

Variables affecting operating efficiency of the Utilizer include log inventory at the machine, size and type of landing, materials handling and maintenance at the machine, and procedures for moving the machine from landing to landing.

• Maintaining an inventory of chippable wood at the machine at all times is critical to the economics of the operation. Because delays in chipping for lack of logs are costly, a substantial cold deck is required at the machine. Considerable reskidding was required to build decks to adequate size. Hot logging to the machine under the conditions surrounding these tests was not feasible.

• The size and type of landing required for chipping depend on terrain, road system development, and the availability of natural openings. Conceivably, the landing requirements could vary from an area that needs no special preparation, such as having the chipper operate on the road from logs decked at roadside, to a completely cleared forest area large enough for the chipper, and log deck, plus van turnaround. In these tests, landings averaged about one-half acre and were roughly square. They were slightly larger than those normally required for loading saw logs and pulpwood. Generally there are adequate openings for landings in the ponderosa pine type, with only minimum additional clearing required. In the spruce-fir type it may be necessary to completely clear a heavily timbered site. Landings must have sufficient level space for the Utilizer, which does not operate properly unless the two sections are well aligned. Ground conditions at the land-

ing must be sufficiently solid to withstand the weight of the Utilizer and loaded chip vans.

• Theoretically, it should be feasible for skidders to deck logs at a debarker-chipper landing within reach of the machine's self loader. However, only very small decks can be accumulated in this way, and such operation is essentially the same as hot logging. In practice, a front-end loader was needed at the landing to help sort and stack logs for easier loading into the debarker-chipper. The additional cost of the front-end loader, which can also be used for other purposes such as spreading bark, must be weighed against lower efficiency in operating the Utilizer.

• Moving bark away from the debarker-chipper was also a problem. The machine's self-contained equipment includes a transverse conveyor belt that can discharge bark to either side of the machine. To prevent clogging of the belt and its drive mechanism, the discharged bark must be cleared away frequently. In the test, the debarker-chipper "ground man" did this by hand in conjunction with the front-end loader, which bladed and spread or piled the bark. This method was time-consuming and not entirely satisfactory. In an ongoing operation, a secondary conveyor to move the bark farther away from the machine might be a better solution, even though it would make decking and loading more difficult on the discharge side and present an additional moving problem.

• The Utilizer may be moved from landing to landing as two separate units, as in over-the-road transport, or with the units hooked together in the operating mode. The latter method theoretically takes much less time since unhooking and rehooking operations are eliminated. Under the conditions of this test, however, it was often not feasible to move the Utilizer as one unit due to difficult terrain, poor road conditions, or lack of maneuvering space. A better arrangement for pulling the units from landing to landing should be developed. In the test a truck tractor was used, often assisted by the front-end loader or a skidder. In regular operation the manufacturer suggests the use of a dolly, equipped with a fifth wheel and tongue, that could be easily positioned under the front coupling of the Utilizer and attached to a crawler tractor or skidder.

5. Chips produced were of high quality.

Three general classes of pulp chips were produced in this test — debarked chips entirely from ponderosa pine, chips with bark from ponderosa pine, and debarked chips from combined live and dead timber of an uncontrolled mixture of Engelmann spruce and subalpine fir. All were found to be suitable for pulp production by the kraft process used at the Snowflake mill. Both classes of debarked chips compared very favorably with chips from other sources. Chips with bark, while less desirable, were satisfactorily processed without major changes in the pulp-

ing process by blending them with debarked chips. Chips from mixed dead and live Engelmann spruce and subalpine fir apparently caused no problems despite the fact that dead chips had an average moisture content of 42 percent, compared to 95 percent for live chips, based on the ovendry weight of the wood. The sieve size of chips produced from live timber was slightly larger than for dead chips, but the difference is probably not of practical importance.

6. Bark disposal at the chipping sites was not a major problem.

It was anticipated that bark accumulations at the inwoods chipping sites would present a major disposal problem. This did not prove to be the case. Ordinarily the concentration of bark was limited by the relatively small volume of timber chipped at one landing. Even in Colorado, where more than 500 tons of chips were produced at a single landing, the bark accumulation was not considered a major management problem, due in part to the large number of dead logs chipped that had little bark.

7. Environmental benefits were realized and impacts were less than expected.

Environmental benefits were expected from the inwoods chipping system as a result of additional slash removal. These benefits were generally realized. Some adverse impacts were also expected due to the need for larger landings, heavier road use, and bark disposal problems. These impacts were less than expected. Specific conclusions are:

The capability of utilizing material that would otherwise remain in the forest as debris under conventional logging practice was particularly beneficial in the Colorado test area. Large volumes of standing and down cull timber were utilized in addition to commercial thinnings.

Soil and site disturbance was generally comparable to conventional logging and within acceptable limits for forest management purposes. Bark disposal at chipper landings proved to be much less of a problem than expected. In Arizona, where bark was scattered and spread at the landing, the problem was nil. In Colorado, where the bark and unchippable chunks were piled for later disposal, the total accumulation was modest and disposal is not expected to create any more of a problem than conventional slash treatment.

Esthetic advantages of harvesting by this system, as compared with conventional multiproduct logging, were negligible in Arizona. In Colorado, considerable esthetic improvement resulted from removal of windthrown timber and other debris.

Other environmental impacts were not quantified, but a reconnaissance of the sites following harvest suggested that water runoff and stream sedimentation would not be significantly chang-

ed, wildlife and range habitat should be modestly enhanced, and timber regeneration prospects should be marginally improved. Despite significant differences in timber type and ground, terrain, and soil conditions, these environmental impacts were substantially similar on the two test areas.

THE PROBLEM

The Nation's requirements for wood and wood fiber are expected to rise dramatically in the remaining years of this century as a result of population growth, the energy situation, and other factors. These expanding requirements can be partially met by more intensive silviculture. However, due to the added investment required and environmental constraints, timber production will not likely increase as rapidly as requirements. The tendency will be for prices to rise and some needs to go unfulfilled. Within the past 5 years, two temporary periods of imbalance between requirements and available stocks have demonstrated the drastic consequences of a wood shortage. Meteoric price rises and unmet needs resulted in both instances from relatively small deficits between the wood and fiber sought and the amount available. One way to help offset such impending shortages is to use our existing timber resources more efficiently. This means, among other things, developing ways to utilize more of the trees and parts of trees that now go to waste.

Substantial progress has been made in fuller utilization of timber, but the wood and fiber yield of some forests could be further increased by as much as 50 to 100 percent if material not presently utilized could be economically harvested. While this degree of waste may seem intolerable, it cannot be easily corrected. The high cost of removing small trees and debris from the forest, compared to their relatively low value in industrial products, makes them generally uneconomic as sources of raw material. Having product prices rise sufficiently to cover these higher raw material costs is not a desirable alternative. Therefore, the most productive approach to complete utilization appears to be reducing the cost of harvesting, handling, and transporting these waste materials to a place of manufacture.

PURPOSE OF STUDY

The underlying purpose of this study was to find a more economical and more environmentally beneficial way to produce pulp chips from small trees and the residues left after conventional timber harvests. More specifically, the intent was to demonstrate an inwoods debarking-chipping system that is being used successfully elsewhere, and determine whether it is a feasible

way to make pulp chips in the Four Corners region.

BACKGROUND

Wood to be chemically pulped for paper is chipped at some stage before it is reduced to fiber. These chips are fairly precisely engineered, generally 1/2 to 1-1/4 inches along the grain, about 1 inch across the grain, and about 3/16-inch thick. Conventionally these chips are made at the pulp mill from small logs (pulpwood), at sawmills from slabs and edgings, or from veneer waste at plywood plants. In recent years, however, interest has increased in producing pulp chips in the forest or at points intermediate between the forest and mill. Several operators in the South, East, and Northwest have adopted this practice and apparently find it advantageous. The incentives are to be able to economically utilize a higher proportion of the timber and residue available in a forest, and to reduce the cost of handling and transporting the wood from forest to mill.

The technology and economics of the pulp and paper industry generally permit only a small fraction of bark to be included in the pulp, since bark has a negative effect on both the properties of paper and the economics of processing. Thus pulp chips are usually made only from trees or residues that have the bark removed, and systems for producing pulp chips in the forest, as well as at the mill, necessarily include a debarking mechanism. The system tested in this study had both debarking and chipping capabilities and the pulp chips produced were of a quality comparable to those produced at mills. The cost is substantially higher than if the chips were made from wood with bark still attached, however. This latter approach, "whole tree chipping," has now become technically and economically feasible for some pulping processes, and is an alternative discussed later in this report.

Another important aspect of inwoods pulp chip production is the availability and location of markets for the chips. The market situation in the Four Corners region is unique in that only one regional firm produces pulp from raw wood — the pulp and paper division of Southwest Forest Industries, Inc., with production facilities at Snowflake, Arizona. While this limits competition for pulp chips, it simplifies analysis of potential supply and demand and makes the opportunities much clearer.

Southwest Forest Industries plans to substantially expand pulp and paper production at its Snowflake facility over a period of several years. It is obvious that more raw materials will be required. This company has therefore been very interested in inwoods chipping, both as a possible supplemental source of pulp chips, and because of potential forest management and environmental benefits.

Expansion plans for the Snowflake complex indicate that capacity will be increased from the current 500 to 1200 tons per day in the next few years. When the planned facilities are all on stream, daily capacity will be 450 tons of newsprint and 750 tons of kraft linerboard. Raw material for the expanded newsprint production will include 45 tons per day of mechanical pulp made from sawdust and 83 tons of semi-bleached kraft, supplemented by groundwood at an unchanged level of 180 tons per day. The remainder of the stock supply will come from recycling newsprint in the amount of 160 tons per day. The bulk of the raw material for the expanded linerboard production will come from increased recycling of waste container clippings and waste corrugated due to their cost advantage over additional chip sources. Chips produced in the forest could be an important supplement to these other raw materials in reaching the expanded production objectives.

Forest managers recognize that the availability of timber for harvest in the future will likely depend on the productivity of the forest and on the condition in which the forest is left after harvest. A major challenge in achieving standards satisfactory to the public and resource professionals is better management of overstocked stands and forest debris, including that resulting from timber harvesting. Forest managers therefore look upon inwoods pulp chip production as a potential tool in achieving such forest management objectives as proper thinning of stands and reduction of undesirable forest residues.

Another incentive for producing pulp chips in remote forest areas is the additional economic activity it would generate. Although this study did not include a detailed economic analysis, a summary estimate indicates that as many as 350 new jobs could result from the proposed Southwest Forest Industries expansion at Snowflake, with an additional annual payroll approaching $3 million. Pulp mill employment would rise by about 135, and an additional 215 workers would be required to provide raw material. Even if it were realistic to assume that only half of the increase would result directly from inwoods chipping, the gain would be significant and the economic benefits desirable. Based on multipliers reported elsewhere for the pulp and paper industry, total economic activity in the Four Corners region could be expanded by approximately $24 million per year.

A feature of inwoods chipping that makes it uniquely attractive for the Four Corners region is that this significant stage of production takes place and substantial value is added in remote areas where many of the region's economic problems lie. It would provide jobs and income for rural communities where these are often erratic or insufficient. Since pulp chips are already being hauled from sawmills scattered through much of the Four Corners region to the Snowflake mill, transportation from other remote communities

may not present an insurmountable physical or economic problem. Also, there is the possibility that a railroad will be extended north from Gallup, New Mexico providing a less expensive alternative for moving chips to the pulpmill.

SPECIFIC OBJECTIVES

The specific objectives of this demonstration test were to:
1. Demonstrate to prospective entrepreneurs and others the operation of a portable debarking-chipping system under Four Corners conditions.
2. Explore the physical limitations of the equipment under Four Corners conditions.
3. Determine economic factors related to chip production with a field chipping system.
4. Define the optimum mode of operation for field chipping equipment.
5. Determine the quality of chips produced.
6. Evaluate the magnitude of the bark disposal problem at woods chipping sites.
7. Evaluate the environmental impacts and benefits of using field chipping equipment.

DESCRIPTION OF INWOODS CHIPPING SYSTEM

The production system analyzed in this demonstration test included combinations of men and machines conventionally used in the study areas for harvesting, coupled with a portable debarking and chipping machine located at landings in the woods. The system also included chip vans of the type normally used for over-the-highway transport of pulp chips.

Trees were felled, limbed, and bucked with chain saws by contract cutters, then bunched and skidded with rubber-tired or tracked skidders. Logs were stacked at the landing partially by the skidders and partially by a front-end loader. The self-loading debarker-chipper blew the chips produced directly into chip vans, which hauled them either to the pulp mill or a rail transfer point. The debarker-chipper worked from a cold deck rather than from logs skidded directly to it.

The central element in the system was the debarking-chipping machine. The unit selected to perform this function was the Logger Model Utilizer, manufactured by the Nicholson Manufacturing Company, Seattle, Washington. This unit, subsequently referred to as the Utilizer, inwoods chipper, or debarker-chipper, was selected because its characteristics seemed best suited to the local requirements. (See Appendix for specifications.)

One essential characteristic was the ability to produce bark-free chips, which at the time of machine selection was considered mandatory for pulp production at Snowflake. The Utilizer meets

this requirement with a high-performance ring debarker. A high production rate was also considered necessary for economic operation, and the Utilizer specifications indicated this capability with resulting low cost per unit of chips. The maximum diameter log that can be debarked in this model Utilizer is 18 inches, which was sufficient to handle most, but not all, of the material available for chipping. Minimum diameter that can be debarked is about 3 inches. There is no maximum limit on length, but logs must be at least 6 feet long to feed through the debarking unit without jamming. Figure 2 illustrates some of the size variation experienced in the test.

Fig. 2. — Variation in piece size typical of spruce-fir timber harvested in the test. Chippable material included many smaller pieces like those seen here.

Feed-rate for the machine when producing chips of the desired length of ⅝ inch is listed at 85 feet per minute. The Utilizer requires an operator who loads timber into the infeed conveyor and controls the debarking and chipping units. A ground man or assistant to the operator is required to perform general maintenance and to prevent and help dislodge jam-ups.

A front-end loader worked at the landing in conjunction with the Utilizer. The front-end loader removed bark from the end of the bark conveyor when necessary, and also repositioned logs from the log deck to put them within easy reach of the Utilizer's loader. Bark was spread on the landing in Arizona, but in Colorado, the bark was left piled for subsequent disposal.

Chips were blown directly into vans from the Utilizer. The position of the chip spout on the Utilizer required that the vans be filled from the rear. Vans were capable of holding from 8 to 12 bone dry unit equivalents (9.6 to 14.4 tons),

depending on the size and moisture content of the chips. Chips were hauled directly from the Utilizer to the pulp mill from the Arizona test area. Chips from the Colorado test area were hauled by van to Gallup, New Mexico and reloaded on rail cars for the remainder of the trip to Snowflake.

Since in Arizona saw logs were also being harvested in conjunction with the chipping demonstration, timber to be chipped included both pulpwood trees and tops of saw log trees. Tops were cut from saw logs at the stump, but saw logs and timber to be chipped were skidded and decked together.

Five skidders were used on the Arizona test area: three large rubber-tired skidders with grapples, one rubber-tired tractor with choker cables, and one tracked skidder with choker cables. Saw logs were loaded and trucked to the sawmill before the remaining material was chipped. Although not anticipated, considerable reskidding was required after saw logs were removed to concentrate small decks into larger ones. Reskidding was believed to be more efficient than moving the Utilizer frequently.

In the Colorado test, most initial skidding was done by two skidders, one rubber-tired and the other tracked, both with choker cables. About two-thirds of the total volume was reskidded by two large rubber-tired skidders with grapples.
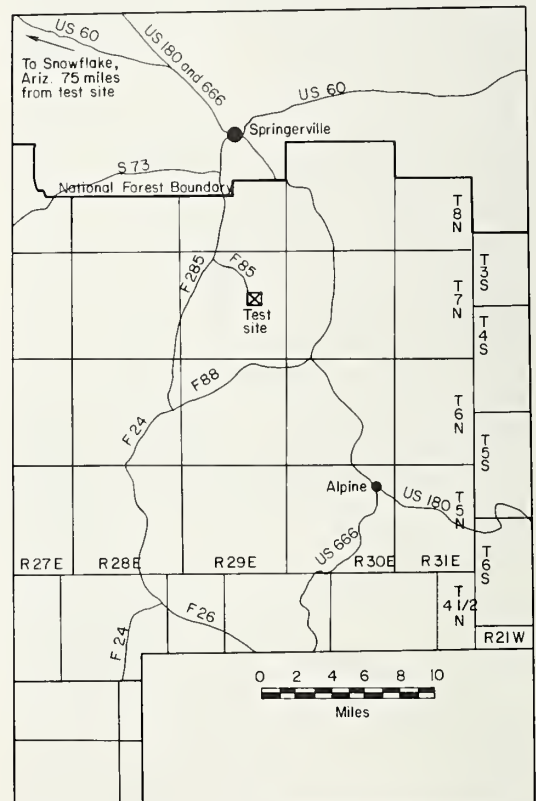

Fig. 3. — Location of the Canyon timber sale test site, Apache National Forest, Arizona.

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CHARACTERISTICS OF TEST AREAS

The Arizona test area was on the Springerville Ranger District of the Apache National Forest (fig. 3). It was part of an ongoing multiproduct timber sale and included 276 acres. The timber type and topography are illustrated in figure 4. The uneven-aged timber stand was marked for partial cutting. Ponderosa pine was the predominant species with Douglas-fir, white fir, juniper, Gambel oak, and pinyon pine interspersed. There was very little down and dead timber on the test area, and none was skidded or chipped. Elevation on the test area varied from 8,100 feet to about 8,700 feet.

For the Colorado portion of the inwoods chipping test, logs were taken from a 36-acre tract on the Dolores Ranger District of the San Juan National Forest at an elevation of about 10,730 feet (fig. 5). Major tree species in the stand are Englemann spruce and subalpine fir. The tract had been logged for sawtimber more than a year prior to the inwoods chipping test.

The Colorado test area had a large volume of down and standing dead timber (fig. 6). Although the pulp mill had not previously utilized chips

Fig. 4. — *Typical topography and ponderosa pine timber on the Apache National Forest test area.*
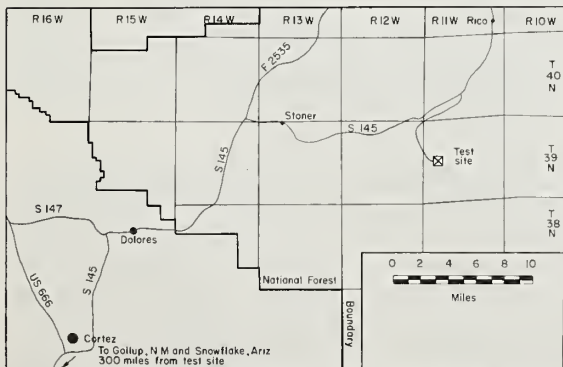

Fig. 5. — *Location of the Roaring Fork timber sale test site, San Juan National Forest, Colorado.*

Fig. 6. — *The San Juan National Forest test area had large volumes of dead and down timber.*

from dead timber, it was agreed that some would be harvested from this area. Therefore, all dead timber more than 50 percent sound was brought in with the spruce-fir thinnings.

DATA COLLECTION

Major data requirements in this study were stand characteristics; production costs, rates, and volumes; and resource impacts. To collect all necessary information and facilitate subsequent processing and analysis, special forms were developed for each type of data.

Plot Data

A full description of the forest stands on each test site was recorded to establish an environmental baseline. Future stand changes may be measured against these base data. Also, stand data on cut trees and residue pieces were used to help determine the volumes harvested in various categories, as discussed in later sections on chip yields and residue characteristics. Data were taken before harvest and again after harvest to determine the changes resulting from harvesting.

One-fifth acre plots were first laid out on maps of the sale areas. Locations were fixed by using a systematic grid system overlaid on the sale area map. On the ground a plot was located by pacing from reference points. It was then marked by a wooden stake at plot center, and by reference to two distinctive "witness trees." Site characteristics recorded were aspect, slope (percent), surface type, and brush density. Trees were classified by species, diameter, timber cutting mark (if any), crown class position, live or dead, and probable cause of damage if evidence was visible. Downed timber was also measured for inclusion in the residue category. To be included a piece had to be more than 4 feet long and greater than 3 inches in diameter at the small end. From these data, residue pieces which fit any specified inwoods chipping standard can later be "sorted out" and scaled for volume. As an example, since the Nicholson Utilizer could take only pieces greater than 6 feet in length and less than 18 inches in diameter, it was useful to be able to estimate the volume of residues within these limits. The computer program for plot analysis can be set up to screen the residue pieces for any desired range of dimensions if they are above the sampling minimum.

Shrubs and seedlings were counted on a second plot of 1/50 acre, concentric on the center of the 1/5-acre plot. Categories included the major tree species found in the stand, plus a breakdown of deciduous and evergreen shrubs.

Ground disturbance is one of the most visible environmental effects of logging. Selected plots were measured to determine the extent and severity of this damage. Proportions of the plot in a series of soil disturbance categories were determined by observing the soil surface at each of 50 steps along two radial transects from the plot center.

Harvesting Production Data

Data of several types were obtained for measuring production performance in the test, and for predicting performance under other circumstances. Generally, these data were collected for each of the basic harvesting functions in the form of time and motion measurements.

For felling and related functions, a stopwatch was used to measure the time required to fell, limb, and buck the tree, and for traveling from tree to tree. Factors that influenced these times include stump diameter, top diameter, species, distance between trees, ground surface, and ground condition. These data can be used to formulate predictive equations by regression analysis, and to establish statistical probability distributions for simulation modeling.

A similar approach was applied to data gathering for the skidding function. Time required for each part of the skidding cycle was recorded and correlated with factors most likely to influence performance, including skidding distance, amount of brush cover, ground slope, and ground surface condition. "Travel outbound" from the deck to felled trees is affected by these factors, as are the "bunch," "choke/grapple," and "travel inbound" subcycles. Other factors affecting the "bunch" and "travel inbound" subcycles are the number and volume of logs picked up and carried by the skidder. Information about the logs carried in each skid turn was recorded and used to compute volume.

Data On Inwoods Debarking — Chipping

The goal of gathering data on the inwoods debarking-chipping operation was to measure the Utilizer's productivity, and determine the patterns and causes of any delays or stoppages. Diameter of each log was pre-measured or visually estimated at the time of loading on the chipper. Log length was measured by a scale marked on the Utilizer infeed. Log type was determined according to the following breakdown:

Log type	Characteristics
1. Pulp log	A tree or butt log from a tree marked as a pulp tree, or a saw log or butt log from a saw log tree which was chipped because of poor quality.
2. Sawtimber top	An upper log taken from a sawtimber tree, or an upper log from a pulp tree.

3. Cull and salvage log A log from timber that was down dead, or standing dead at the time timber was being felled.

4. Decked sawtimber cull A log skidded and decked with sawtimber, but left behind as cull when the remainder of the saw logs were loaded. These logs usually had been decked more than a year.

5. Broken log top Any green log which was broken on the large end. These pieces may have been broken during skidding, decking, or loading onto the chipper infeed, and couldn't be identified as coming from a certain log.

If a delay occurred during the normal work day, which usually extended from 0730 to 1630, it was recorded in "military" time, along with a code for the cause.

These general procedures were followed in both the Arizona and Colorado test areas. However, the high proportion of dead wood harvested in Colorado indicated a need to evaluate the characteristics of the chips produced more closely. Potentially, pulping characteristics and moisture content of the chips could vary significantly from log to log, depending on whether it came from a live or dead tree and, if dead, for how long. A better estimate of moisture content than could be obtained from the customary single sample per van load was particularly needed to establish the bone dry weight of chips produced. To meet this special requirement, chips produced from randomly selected live and dead spruce and fir logs were sampled as they were blown into the van. Larger chip samples were also collected periodically for shipment to the Forest Products Laboratory, Madison, Wisconsin, where they will be evaluated for pulping quality and potential use in particleboard.

RESULTS

Yield of Chips and Chip Quality — Arizona

Fifty-four van loads of chips from the Arizona test site were delivered to Southwest Forest Industries pulp mill at Snowflake. Chipping, exclusive of setup time, inclement weather days, weekends, and holidays took 31 days from June 25 to August 15, 1973. The gross weight of delivered chips was 1,288.9 tons. When converted to a bone dry basis, the net fiber weight was 49.2 percent of the gross chip weight, or 634.3 tons.

For all practical purposes, dead cull material contributed nothing to either volume or piece count in the Arizona test. Assuming these ponderosa pine timber stands are typical, there is little reason to expect much yield from dead or down trees from similar stands. Yield of green pulpwood on this multiproduct site averaged 161.4 cubic feet or 1.7 cords[2] per acre, less than many commercial pulpwood stands could produce. Table 1 summarizes the type and quantities of timber chipped on the Arizona test area.

Personnel at the Snowflake pulp mill were satisfied with the pulping qualities of chips supplied from the Arizona test site, including 10 van loads of chips produced from wood with bark still attached, sent to the mill for test purposes. Qualitative results of these tests indicated no appreciable difference in pulp quality, since only small proportions of undebarked chips were blended with debarked ships.

Yield of Chips and Chip Quality — Colorado

Forty-eight van loads of chips were produced in 18 days of chipping on the Colorado test area. Gross weight of these chips was 801.5 tons. Bone dry weight was 63.1 percent of the gross weight, or 505.4 tons.

Although the number of pieces of dead material (2,683) was slightly less than the number of green pieces (2,717), dead material contributed significantly more volume. Green pulpwood averaged 515.9 cubic feet of solid wood or 5.3 cords[2] per acre. Dead and cull material contributed 830.9 cubic feet or 8.5 cords per acre, 61.7 percent of the total volume chipped from the test area. Much of the dead timber was blow down, some of which occurred after a saw log harvest over a year before the chipping test. This yield pattern may have important implications for spruce-fir forest areas where a general woods cleanup of dead and down timber could be combined with a conventional pulpwood harvest. Currently, however, no pulpwood is harvested in Colorado. Table 1 details chip yield statistics for the Colorado test area.

A preliminary evaluation indicated that chips from both live and dead wood can be pulped satisfactorily by the sulfate pulping process used at the Snowflake mill.

Further analysis of these chips produced in Colorado indicated that moisture content differed significantly between chips from live and dead trees, as would be expected. The average moisture content of chips from live trees was 95 percent, contrasted with only 42 percent for chips from dead trees. There was also a significant difference in moisture content between chips produced from live Engelmann spruce and from live subalpine

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[2]The conversion of cubic feet to cords assumes 97.8 cubic feet of solid wood per cord.

Table 1. — Summary of Arizona and Colorado harvest statistics by log type

Log type[1]	Pieces chipped		Volume chipped		Ave. volume per piece
	No.	% of total	Cu. ft. of solid wood	% of total	Cu. ft. of solid wood
Arizona					
Green					
Pulp tree	3,684	58.3	29,426	66.1	8.0
Sawtimber top	1,910	30.2	13,260	29.8	6.9
Broken log tops	676	10.7	1,557	3.5	2.3
Subtotal	6,270		44,243		7.0
Dead					
Cull and salvage	49	.8	286	.6	5.8
Cull decked sawtimber	1	.0	17	.0	17.0
Subtotal	50		303		6.1
Total	6,320	100.0	44,546	100.0	7.0
Colorado					
Green					
Pulp tree	2,373	43.9	17,675	46.5	7.4
Sawtimber top	5	.1	7	.0	1.4
Broken log tops	339	6.3	889	1.8	2.6
Subtotal	2,717	50.3	18,571	38.3	6.8
Dead					
Cull and salvage	2,678	49.6	29,902	61.7	11.2
Cull decked sawtimber	5	.1	12	.0	2.5
Subtotal	2,683	49.7	29,914	61.7	11.2
Total	5,400	100.0	48,485	100.0	9.0

[1]For a definition of the log type, refer to the section on Data Collection.

fir — 82 percent versus 107 percent, respectively. Moisture content of chips from dead material did not vary significantly with either species or log diameter, however.

The average chip size, as measured by a standard sieve method, was 0.51 inch for spruce and 0.50 inch for fir, not significantly different. Chips from live timber averaged 0.53 inch while those from dead timber averaged 0.49 inch. Though statistically significant, this difference is probably of little practical importance.

Costs

The total costs of getting timber from the stump into pulp chips and then delivered to the pulp mill are shown in table 2. Costs for the individual functions involved in inwoods chipping are also shown for the two test areas and for a conventional multiproduct system in Arizona.

The assumed machine and labor rates used in computing costs are shown in appendix table 4. The hourly and daily cost computations for the Utilizer are given in appendix table 5.

Except where noted, the costs actually experienced are given. A major exception is the computed chipping cost used. In computing this cost we eliminated downtime due to problems believed to be peculiar to this study and not likely to be encountered in an ongoing operation.

Falling, Limbing, and Bucking

Costs of falling, limbing and bucking timber from a selection cut in a ponderosa pine stand should be slightly less with inwoods chipping than if roundwood pulpwood were produced. The reason for this is that roundwood pulpwood must

be measured and cut to lengths in multiples of 5 feet. With inwoods chipping, slightly longer lengths should be obtained than for pulpwood roundwood, although slightly more time may be required for limbing. In the field test, falling, limbing, and bucking required 17.2 minutes per hundred cubic feet for inwoods chipping versus 20.7 minutes per hundred cubic feet when roundwood was produced. Limbing and bucking took about 0.3 minute longer per tree when it was necessary to measure pulpwood lengths. Top diameters were about 0.4 inch larger (inside bark) where pulpwood was cut to lengths in multiples of 5 feet. However, the cost of falling was contracted at the same rate for conventional multiproduct harvest and inwoods chipping as reported in table 2.

Table 2. — Total unit cost of chips delivered to the Snowflake pulp mill from the test areas in Arizona and Colorado, in comparison with a conventional system for producing chips (cost of stumpage excluded)

Function	Inwoods chipping[1]		Conventional multiproduct system in Arizona (ponderosa pine)
	Ponderosa pine (Arizona)	Spruce-fir (Colorado)	
	Dollars per bone dry unit[2]		
Falling, limbing and bucking	4.60	4.26	4.60
Skidding and decking	9.08	7.75	9.08
Reskidding	2.92	2.29	—
Loading pulpwood	—	—	2.80
Chipping	[3]19.46	[3]18.51	—
Total inwoods cost	36.06	32.81	16.48
Truck haul pulpwood	—	—	4.56
Slashing to 5' length	—	—	7.12
Rail haul pulpwood	—	—	3.53
Chipping	—	—	3.20
Truck haul chips	13.64	24.86	—
Scale and reload	—	.40	—
Rail haul chips	—	7.89	—
Unloading, scaling, etc.	.40	.40	.75
Total out-of-woods cost	14.04	33.55	19.16
Total cost	50.10	66.36	35.64

[1]Costs for inwoods chipping are based on production of 528.5 bone dry units in Arizona and 421.1 bone dry units in Colorado.
[2]A bone dry unit is 2,400 lbs. of chips at zero moisture content. This unit is roughly equivalent to a cord.
[3]Cost adjusted to eliminate downtime that could probably be eliminated in an ongoing operation.

In the spruce-fir type in Colorado, the volume of down timber inhibited movement of the timber faller and made limbing and bucking very difficult. Diameter of the timber being felled in this area was slightly smaller than in Arizona. The average rate was 36.5 minutes per 100 cubic feet.

Skidding

For green timber, utilization is slightly greater with inwoods chipping than when logging roundwood due to slightly smaller top diameters. Skidding rates and costs should be comparable between the two systems, with skidding for inwoods chipping having a slight advantage because of slightly increased volume per

piece. In practice, however, considerable reskidding or forwarding was done to increase the volume of wood available at individual landings. This obviously increased total skidding costs, but reduced the cost of moving the Utilizer and preparing additional landings.

Initial skidding on the ponderosa pine area in Arizona averaged 22.7 minutes per 100 cubic feet for the five skidders. This production rate is quite low compared with skidding observed in large sawtimber stands (typically less than 6 minutes to skid 100 cubic feet), but it is better than that observed in skidding selectively cut ponderosa pine pulpwood on similar terrain (30.8 minutes per 100 cubic feet). The terrain was undoubtedly a factor in reducing skidder production in this test, since abrupt changes in topography interfered with skidder travel. The skidding cost for Arizona reported in table 2 is that reflected by company records.

On the spruce-fir test area in Colorado, higher volume per acre and more favorable terrain but longer distances resulted in 27.2 minutes of initial skidding time per 100 cubic feet. The average initial skid distance was less than 200 yards. About two-thirds of the volume was reskidded, however, with reskid distance averaging about ¼ mile.

Debarking-Chipping

No major differences in production rates or costs were expected for falling or skidding functions in the inwoods chipping system as compared with conventional multiproduct harvesting. The main interest in this study was therefore the actual debarking-chipping operation.

Data furnished by the chipping machine manufacturer prior to the demonstration test, adjusted to the conditions expected in the test, indicated that the debarking and chipping cost should not exceed $6.60 per unit (including cost of a front-end loader accompanying the chipper). We therefore anticipated substantial net economies, since inwoods chipping would eliminate the need for a pulpwood yard, where the cost of cutting logs into pulpwood lengths and reloading them onto rail cars was running about $7.12 per cord, as well as the $3.20 per unit cost of chipping at the mill. These economies were not realized in the test, primarily because the debarker-chipper had much more downtime due to mechanical problems than expected, and production rates when the machine was running were less than expected. It also took considerably longer to move the machine between landings than had been predicted by the manufacturer. Much of the excessive downtime can probably be attributed to the extensive modification of the machine's power plants that was necessary to permit it to operate at the test elevations. The machine's mobility could also be improved with some fairly minor changes in the towing arrangement, which would be practicable in an ongoing operation. Where possible, such improvements have been taken into account in projecting long-term costs of an inwoods debarking-chipping system.

Operation of the debarker-chipper was monitored continuously throughout the study. Starting and ending times for chipping each van load were noted. Any delays of one minute duration or longer were noted along with the cause. An analysis of these times showed that the machine was operating only 54.1 percent of the total available time (time when the Utilizer either was producing or could have been had it not been broken down or jammed). It had been anticipated that the machine would be producing chips during more than 80 percent of the available time.

Actual production rates were 7.9 units per net operating hour in Arizona and 7.6 units per hour in Colorado, compared with 10 units that had been projected. The reduced rate was due to (1) difficulty in loading timber into the machine fast enough to utilize its full debarking-chipping capacity, and (2) slowdowns of the chipper resulting from power loss at high altitudes. The high altitude was more of a factor in Colorado than Arizona because of the large proportion of dry dead timber, which requires greater power for chipping.

The loader unit on the Utilizer was designed for six load cycles per minute. In preliminary analyses a maximum of four cycles per minute was assumed to allow for delays in grappling and positioning logs. In actual operation, however, the loader was seldom able to average more than two pieces per minute in producing an entire van load of chips.

Moving the debarker-chipper from landing to landing also presented some unexpected problems. According to specifications, if the debarker-chipper units were left coupled, it should take 5 minutes to prepare for moving; then the machine could be moved at the rate of 100 yards per minute, and 5 minutes would be required to set the machine at the new landing. If the two units were to be uncoupled, it would take 20 minutes of preparation; then the units could be moved at 30 miles per hour over good roads, and 20 minutes would be required to recouple the units and set the machine at the next landing. Actual moving times were much greater than predicted. Minimum moving time was 55 minutes if the two units were left coupled and 95 minutes if the two units were uncoupled and moved separately.

Moves were usually short (between 100 and 400 yards). In the ponderosa pine test area there were 11 landings and 10 moves of the Utilizer. It was therefore desirable to move the machine in one piece if possible. However, terrain features required that the Utilizer sometimes be moved in two units, even where moves were short. The average moving time used for determining chipping costs was 65 minutes, based on the assumption that on ¼ of the moves the Utilizer would have to be moved as two separate units.

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Hauling

Ton mile costs for a chip van should be about the same as for a log trailer, but about 10 percent of the weight of roundwood pulpwood is bark, so, hauling debarked chips should be somewhat cheaper. Actual hauling costs depend in part on efficiency of the debarker-chipper. Volumes hauled per day will decrease and the cost per unit increase if vans are not fully utilized.

The chip hauling costs in Arizona included a round trip cost of $92 from the woods to the Snowflake mill (75 miles) and a rental cost of $25 per day for each of five vans. This gives a total hauling cost of $13.64 per unit for a production rate of 29.4 units per day.

In Colorado, chip hauling was contracted for $140 per round trip from Dolores, Colorado to Gallup, New Mexico (146 miles), an average of $15.96 per bone dry unit. There was also a cost of $150 per day for two truck tractors used to shuttle loads from the woods to Dolores. A cost of $25 per day was added for rental on each van. Thus, the total truck hauling cost for a production rate of 30.9 units per day in Colorado was $24.86 per unit to Gallup, a total distance of 184 miles. The rail hauling cost from Gallup to Snowflake, a distance of 116 miles, was $7.89 per unit of chips, plus $0.40 per unit for weighing and reloading on rail cars. The total average hauling cost for chips produced in Colorado was therefore $33.55 per unit.

This high transportation cost alone makes Colorado questionable as a source of chips, even with significant reductions in cost of inwoods chipping. However, increasing demand for pulp and a resultant price increase, coupled with a limited wood supply close to the pulp mill, could make Colorado pulpwood harvesting feasible in the future. Also, there are prospects for a new rail line to be constructed about 100 miles north from Gallup for other purposes. Assuming this rail line would be available to Colorado shippers, substantial reductions in freight costs for Colorado-produced pulp chips should be possible.

Projected Inwoods Debarking-Chipping Cost

Chip production in these tests averaged only 15 bone dry units per day over the 63-working-day period the debarker-chipper was available for operation. At this rate the cost of chipping would be about $38 per unit. Obviously, this cost is too high to be economic for pulp production under present conditions. However, the 63-day period included much time lost due to kinds of delays typical of pilot operations. Such factors as organizing and training the crew to operate an unfamiliar system, getting the debarker-chipper to run properly at high altitudes, logistic problems stemming from lack of experience, and many other delays greatly reduced the time in

production and therefore raised unit costs.[4] While it may be argued that this was the actual experience and represents the best estimate of productivity, we consider it unrealistic to use this rate as a basis for projecting costs for an ongoing operation. To get a more realistic view of long-term performance, we have assumed that many of these inefficiencies could be eliminated over time, and that the improved levels achieved would provide a better basis for cost estimates. Since the degree of improvement expected is judgmental, we have projected costs under several sets of assumptions, as depicted in curves I through V, Figure 7.
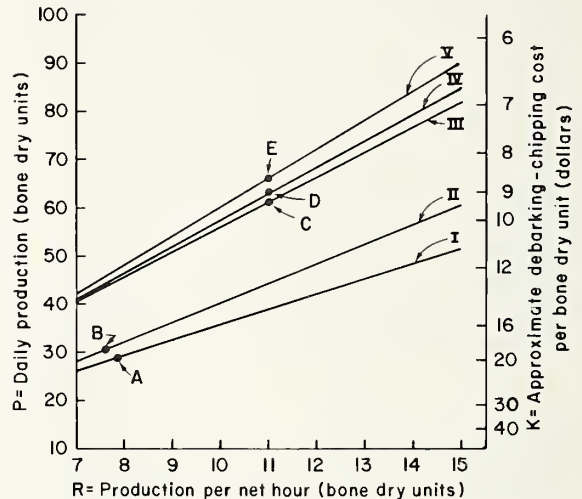

Fig. 7. — Daily chip production and approximate chipping cost by net production rate according to log deck size, proportion of available time in production, and moving time between log landings.

The equations for the two ordinates or vertical scales of the curves in figure 7 are given by

$$P = \frac{H}{\dfrac{1}{RT} + \dfrac{M}{U}} \text{ and } K = \frac{572.16}{P}$$

where:

P = daily production in units of chips.
H = hours per day available for moving Utilizer or chipping.

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[4] *Time available for operation in the test totaled about 500 hours. Of this total time only about 128 hours were actually spent in producing chips. The remainder of the available working hours included approximately 107 hours when the debarker-chipper was inoperable; 15 hours for routine maintenance; 28 hours for moving the debarker-chipper (which could possibly be reduced to 10 hours with improvements in design and crew experience); 60 hours spent waiting for vans at the chipper; 15 hours to change vans; 20 hours required to move from one test area to the other; 40 hours attributable to logistic and crew delays; 45 hours lost due to weather conditions; and 40 hours lost for other miscellaneous reasons.*

R = units of chips produced per net production hour.

T = percent of time available for chipping that the machine is actually in production as a ratio.

M = moving time (in hours) between decks.

U = average number of units per deck.

K = cost per bone dry unit.

572.16 = daily cost of operating Utilizer system.

Note that the abscissa scale is in terms of R, and five combinations of the remaining variates as shown below account for the different curves.

Curve	T	U	M
I	54	48	1.08
II	54	—	None
III	80	48	.40
IV	80	80	.40
V	80	—	None

In addition it was assumed that 7.5 hours per day were available for chipping or moving for each curve.

Curve I represents conditions similar to those that would have been encountered on the Arizona test area if startup problems and weather delays were eliminated. (The cost of weather delays is discussed further in a later paragraph of this section.) Point A on this curve represents the 7.9 bone dry units per net production hour experienced in actual operation. A daily production rate of 29.4 bone dry units results from this hourly rate when operating hours are reduced to reflect experienced downtime on the Utilizer, including moving time at a level that should be attainable. Production cost at this rate is $19.46 per unit.

Curve II generally represents conditions that would have been encountered in the Colorado test area without startup and weather delays. Point B on this curve represents the 7.6 bone dry units per net production hour experienced in actual operation. A daily production rate of 30.9 units results from this hourly rate when operating hours are reduced to reflect experienced downtime on the Utilizer. Move time was not deducted since all production was at a single landing. Production cost at this rate is $18.51 per bone dry unit.

Since the proportion of time the debarker-chipper was actually in production seemed to be less than could be expected in an ongoing operation, curves III, IV, and V were developed to reflect more probable and economically necessary levels. The Utilizer's production rate while actually operating also appeared to be lower than should be achieved with further experience. It is therefore assumed that a production rate of 11 bone dry units per net operating hour should be possible for most types of timber. This assumption is represented by Point C on curve III, with a resultant daily production of 61.5 units at a cost of $9.30 per bone dry unit.

The unit cost difference between Points A and C is $10.16. Of this, $5.67 is attributable to changing the proportion of operating time from 54 to 80 percent, $3.41 to increasing production per net hour from 7.9 to 11.0 units at 80 percent operating efficiency, and $1.08 to decreasing moving time between landings from 1.08 to 0.4 hours. Changing the average deck size at Point C from 48 units to 80 units results in Point D on curve IV, where daily production is 63.2 units at a cost of $9.05 per unit.

If all assumptions about Point D were retained and it were further assumed the machine was at a semipermanent location (no moving time), daily production would be 66 units, reflected by Point E on curve IV. Cost per unit would be $8.67, or a reduction of $0.38 per unit from Point C.

The most critical assumption in decreasing debarking-chipping costs is the ability to increase the proportion of operating time from 54 to 80 percent of available time.

Inclement weather would likely cause some downtime because of road conditions in an ongoing operation as it did in the test. A downtime of 10 percent, with only fixed costs for the Utilizer and front-end loader being incurred, would result in an increase in unit cost of chipping of $1.24, $1.19, $0.60, $0.58, and $0.55 for points A through E, respectively. Downtime of 20 percent for weather would increase cost per unit $2.79, $2.66, $1.34, $1.30, and $1.24, respectively.

Fixed costs for the Utilizer system are based on an operating season of 1600 hours per year. While it would be difficult to operate "inwoods" for this period of time even in Arizona, it was felt that an owner of such a system would operate at least 9 months and probably year round, even if it meant locating at a mill yard or other intermediate location for several months. Problems and advantages of operating at an intermediate location are discussed in a separate section later in the report.

ENVIRONMENTAL FACTORS

A major objective of this demonstration test was to determine how the inwoods chipping system would affect various environmental factors. It was assumed that the basic harvesting functions would have the same impact as in the conventional systems, since they were essentially similar, but the greater removal of forest residues would be an environmental improvement. Such removal would improve esthetics, and provide better protection from fire, insects, and disease.

Bark accumulation was the one expected negative factor in inwoods chipping. In practice, the environmental effect of the waste bark proved to be negligible in Arizona and easily managed in Colorado.

While exacting techniques for measuring environmental impacts were either unavailable

or outside the scope of this study, we attempted to evaluate them as thoroughly as practicable.

The reduction in volume of residues was analyzed most definitively. Site sampling and reconnaisance also provided a useful index of soil disturbance. A new experimental technique is being used to evaluate the esthetic improvement obtained by this harvesting system (Daniel, et al. 1973). It will be some time before the results of this analysis are known.

While this attempt at evaluating the environmental effects of harvesting in an objective frame of reference is not as definitive as we would like, it provides some useful information and paves the way for further development needed in this field. The following summarizes the results of the environmental evaluations.

Residue Left After Debarking and Chipping

As would be expected, timber stand differences in Arizona and Colorado resulted in different amounts and distributions of residue remaining after harvest. The major differences are that Colorado spruce-fir stands typically are denser and have more down timber than Arizona ponderosa pine stands. Table 3 summarizes estimated residue volumes and pieces, by size category, left on the ground after the chipping.

Before logging, the Arizona test site had little chippable residue, as is typical of many southwestern ponderosa pine stands. Following harvest, very little residue remained from the volume generated by logging except branch material not classified as chippable (fig. 8). The volume of green residue left, within the Utilizer size limits, amounted to 14.1 cubic feet per acre. Dead chippable residue was only 2.1 cubic feet per acre. Thus, the total chippable residue after harvest was 16.2 cubic feet per acre. Even if the Utilizer could have effectively processed material less than 6 feet long, only an additional 0.1 cubic feet per acre could have been utilized.

In contrast to Arizona, residue on the ground before logging for inwoods chipping provided a significant part of the chip volume in the Colorado test (fig. 6). However, relatively more residue volume remained after chipping in

Fig. 8. — *Unchippable ponderosa pine slash remaining after harvest on the Apache National Forest test area.*

Colorado than in Arizona because of the large number of marginal pieces that technically qualified for the "chippable" category but were not harvested. Green "chippable" residue not chipped averaged 95.5 cubic feet per acre. However, it was contained in 68.2 pieces per acre, so each piece had an average volume of only 1.4 cubic feet. This figure compares closely with the 1.8 cubic feet per piece left on the ground in Arizona. More dead or dry residue remained on the ground in Colorado than in Arizona. But since the number of pieces was also much greater in Colorado, the average dead piece volume was about the same for both areas. Many residue pieces were barely within the "chippable" category, as defined by Utilizer size limits. These small, marginal pieces are easily overlooked by the skidder operators, and therefore may not be brought to the chipper. It is also apparent that substantial volumes were not chipped because the diameter of the pieces exceeded the 18-inch capacity of the debarker.

Table 3. — Characteristics of residue remaining on the test area after inwoods debarking-chipping

Type of residue	Volume per acre		Pieces per acre		Volume per piece	
	Ariz.	Colo.	Ariz.	Colo.	Ariz.	Colo.
	Cu. ft.		Number		Cu. ft.	
Green						
<6 ft. long >6 ft., large end dia.	0.1	4.2	0.4	11.4	0.3	0.4
<18 in. >6 ft., large end dia.	14.1	95.5	7.9	68.2	1.8	1.4
>18 in.	0	75.7	0	.5	0	168.2
Dry						
<6 ft. long >6 ft., large end dia.	0	13.1	0	11.8	0	1.1
<18 in. >6 ft., large end dia.	2.1	183.5	1.1	61.4	2.0	3.0
>18 in.	15.3	57.1	.4	1.8	38.2	31.4

Soil Disturbance

A survey of the soil cover disturbed by logging on test sites indicated that the degree of disturbance (percentage of soil surface) was proportioned as follows:

	Ariz.	Colo.
1. NONE — no disturbance	38.6	46.4
2. NONE/SLASH — soil not disturbed; covered with residue from logging, or natural disaster.	29.4	22.0
3. LIGHT — observable wheel marks of skidders, etc.; no mineral soil exposed. Litter layer packed; brush layer broken down or bent over. Skidder generally traveled in an area only once.	15.1	16.1
4. MEDIUM — machine wheels or logs broke through litter layer. Mineral soil exposed and compacted. Shrubs broken down. Machines traveled on the same trail several times; wheels did not break into the root mat.	7.9	9.3
5. HEAVY — same conditions as in MEDIUM, with addition of heavily rutted trail and roots severed. Trail used several times as a main trail for long skidding distances. In dry weather, surface dust layer loose and thick. In wet weather, trail can deteriorate rapidly with only a few trips.	9.0	6.2

The proportional area of disturbance was essentially the same on the Arizona and Colorado sites. Both the total proportion of disturbed areas and the proportions of areas in the HEAVY, MEDIUM, and LIGHT disturbance classes were similar. From available evidence in other studies and our results in Arizona and Colorado, it appears that ground disturbance by tractor skidders is quite similar over a wide variety of terrain, logging systems, and timber types (Zasada and Tappeiner 1969, Campbell et al. 1973). In the Zasada and Campbell studies, as well as in this study, topography or logging methods appeared to limit the amount of surface that is heavily disturbed. Zasada's study was done on flat terrain, but repeated runs by skidders were channeled into certain areas. In Campbell's study, steep to rolling terrain naturally limited the placement of effective skid trails.

Average slope on the Arizona test site was 21 percent with a wide variety of terrain. Slope values ranged from 5 to 55 percent. Main skid trails and spur roads were located on the contour as much as possible. In Colorado the test area was located on a ridge top, where the slope was flat to gentle in the upper portions and steeper on the lower parts of the site. Slopes ranged from 2 to 33 percent, with the average being 16 percent. Heavily traveled skid trails could only be placed on the contour and on the ridge top.

Fire Danger

No quantitative attempt was made to determine whether inwoods chipping reduced fire danger compared to conventional pulpwood and multiproduct harvesting. Qualitatively, some minor improvement should be realized in the ponderosa pine type, since volume utilized in the chipping harvest was slightly greater than in conventional pulpwood harvesting due to cutting to a set top diameter rather than 5-foot multiples. Some additional cull material was removed also. Chipping in conjunction with a sawtimber harvest should yield greater benefits, giving about the same net effect as a multiproduct harvest plus the marginal additional benefit relative to pulpwood harvesting.

Other fire-related aspects of ponderosa pine harvesting are essentially the same for these systems. Volume and distribution of branches and needles should be the same, but lopping of tops, required as a fire precaution under most timber sale contracts, may be slightly less time-consuming for inwoods chipping since the diameter of the cut tops will average nearly a half-inch smaller.

In the spruce-fir type in Colorado, an abundance of standing and down dead timber was harvested for chipping. This dead material amounted to slightly over 60 percent of the total volume chipped from the Colorado test area. More than seven units per acre which would have remained as residue under conventional sawtimber harvest were removed. This substantially reduced the total fuel available, and should reduce the hazard of a major fire. It would not have much effect on the initial rate of spread, however, since the residues removed were too large. Improved accessibility would simplify suppression activities.

Esthetics

The greater the quantity of down limbs and timber and the greater the signs of disturbance, the less esthetically pleasing a forest stand seems to be. Considering the small amount of debris present either before or after harvest, it is doubtful that inwoods chipping in the Arizona ponderosa pine type will produce an effect esthetically distinguishable from conventional harvesting to a 4-inch top. When sales contracts call for harvesting trees to an 8-inch top, however, the esthetic benefits of chipping would likely be more obvious.

In the spruce-fir type in Colorado the esthetic impacts of harvesting were potentially much greater. Much of the large volume of dead and down material in these stands was chipped (fig. 9). On the other hand, the removal of large volumes per acre resulted in greater disturbance of the site.

In an attempt to evaluate these esthetic impacts, photographs were taken before and after harvest for the inwoods chipping test. These photos are being analyzed by an experimental process involving review by various audiences to determine comparative esthetic values before and after harvest. Since much of the evidence of harvesting disappears after a year or two, the test areas will be rephotographed 2 years after harvest. These photos will also be evaluated by the panel technique to determine the change in esthetic values.

Fig. 9. — Before and after harvest views of a scenic vista on the San Juan test area.

Other Environmental Factors

It is doubtful that harvesting on either of the two test areas had a measurable effect on other environmental factors.

The volume of timber removed from the ponderosa pine area was quite small, and probably would not noticeably affect water yield or insect and disease potential. Since the harvest did open up the stand, there will likely be some increased growth of forbs and grasses for a few years, and consequent improvement in range and wildlife habitat.

The large volume of dead and down timber removed in the spruce-fir stand may initially accelerate runoff due to the removal of physical barriers, which might slightly increase sedimentation. The removal of physical barriers should also make the area more accessible to big game, but perhaps less desirable for some small-game and non-game species.

More will be learned about the actual effects of harvesting on these environmental factors when the test areas are revisited in subsequent years.

FUTURE DEVELOPMENT OF HARVESTING SYSTEMS FOR PULP CHIPS

The experiences gained in this demonstration test provided considerable insight into how the system might be improved and modified to meet Four Corners conditions. Overall reduction in unit costs is obviously the major challenge.

Intermediate Locations

An alternative to debarking-chipping in the woods or at the pulp mill is to perform these operations at some intermediate point. The debarker-chipper could be set up at one or more semipermanent or permanent locations where it would operate several months at a time or year round. In theory, the same degree of timber utilization could be achieved at such intermediate locations as is possible with inwoods chipping. Instead of chipping at a woods landing, timber to be chipped would be trucked to the intermediate location for debarking and chipping. There chips would be blown into a van or rail car and hauled to the pulp mill.

Advantages foreseen for debarking and chipping at an intermediate point compared with an inwoods location include:

1. Greater proportion of time available for chipping, due to elimination of debarker-chipper moving time.
2. Less downtime due to weather.
3. Easier travel by chip vans, due to no inwoods travel.
4. Greater output per net hour of production, due to greater efficiency in loading.
5. Availability of line electric power for the debarker-chipper, which is more efficient, more trouble-free, and less costly than diesel power.

Possible disadvantages are:
1. Increased handling costs and breakage of small timber due to the extra loading and handling.
2. Increased log hauling costs and problems of getting short pieces loaded on log trucks in the woods.

3. Bark disposal problem at debarking-chipping site.
4. Large inventory space required for concentrating timber at debarking-chipping yard.

Curve V of figure 7, which estimates production if the Utilizer is not moved and downtime due to mechanical breakdown and log jams is reduced to 20 percent of available time, most closely approximates a debarker-chipper operating in a semipermanent setting. If the Utilizer could be redesigned to reduce the time required to move from landing to landing to 0.4 hour as shown by Curves III and IV of figure 7, the debarking-chipping cost advantage at an intermediate location would probably be negated by the additional costs of loading and hauling timber and bark disposal.

There is, of course, the additional consideration of being able to work a longer season and during inclement weather at an intermediate location when an inwoods operation would be shut down. The optimum situation would probably be to debark and chip in the woods in the spring, summer, and fall, and move the Utilizer to a concentration yard during the winter.

A variation on debarking-chipping at intermediate locations would be to chip at a timber concentration or log sorting yard. Logs from surrounding areas are hauled to these yards to provide a better opportunity to sort for alternative uses than deck sorting in the woods, and highly mechanized handling systems permit sorts to be made more efficiently. There is a growing interest in sorting yards in the southern Rocky Mountains; one is already under construction, and there are plans for at least two more to be built within 4 years.

Justification for such sorting yards will depend largely on increasing the value of saw-timber by better log sorting. Chipping at a sorting yard instead of in the woods would seem to be more economical, provided the presence of pulpwood did not create a bottleneck for the log sorting operation. Pulpwood could be brought in in any length, and could either be chipped or bucked into the lengths needed for groundwood. Odd lengths and crooked pulpwood as well as cull saw logs could be chipped at the sorting yard and hauled to the pulp mill in chip form.

Whole-Tree Chipping

One promising way to lower chip costs is to eliminate the debarking requirement. There has been much interest recently in whole-tree chipping — that is, chipping the tops, limbs, and foliage, as well as the bole wood. This requires that chipping be done in the woods, since it is impractical to load and haul whole trees to a mill. It also means that the bark is chipped along with the wood, since it is not feasible to remove bark from very small or crooked material.

Advantages of this system over debarking and chipping in the woods are:
1. It eliminates limbing and thus reduces cost.
2. Since there is no debarking, inwoods equipment and processing are simpler and less costly.
3. Slash disposal is eliminated.

Disadvantages include:
1. Skidding whole trees is probably more expensive and results in more damage to reproduction and the site.
2. The utility of the chips produced is restricted.
3. Special processing is required for whole-tree chips.
4. The waste disposal problem at the mill is increased due to the presence of bark and needles mixed with the wood fiber.
5. Nutrients from the needles and branches are not returned to the site.

There is no doubt that whole-tree chipping can deliver chips to the mill at a lower cost than inwoods debarking-chipping. The two disadvantages that are likely to limit its adoption are damage to the residual stand during skidding, and the need for special processing at the pulp mill. Conventional pulping processes can accommodate only small amounts of bark. While a process for separating bark from whole-tree chips has been developed, it is still in the experimental stage. However, some chips now produced from whole trees in other parts of the United States are being successfully used in paper and other products without complete bark separation.

Multiproduct harvesting, with chipping of whole pulp trees and whole tops of sawtimber, would require limbing the saw log portion of trees and making buck cuts between sawtimber and pulpwood, either at the stump or at a landing. On stands being partially cut, skidding of large whole trees would probably be unacceptable due to damage to the site and the residual stand. Skidding of whole trees should be acceptable on areas being clearcut, and saw logs could be limbed and bucked at the landing.

It seems unlikely that whole-tree or sawtimber-top chipping on multiproduct sales will ever be feasible on partially cut ponderosa pine stands due to skidding damage. In spruce-fir stands, however, because of the general shape of the trees, the site and residual stand are less likely to be damaged when trees are skidded whole.

If whole-tree chipping for pulp chips becomes practicable in this area, it will likely be because of cost reductions in harvesting and not because of the increased volume of pulp chips obtained per harvested tree. The branches and tops now being left in the woods that would be salvaged with whole-tree chipping are small in diameter, and a high proportion of their volume is bark. The yield of acceptable pulp from bark is very low compared to bark-free wood. A prerequisite for any whole-tree chipping, of course, is a process that can economically utilize chips with bark.

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Abstract

Sampson, George R., Harold E. Worth, and Dennis M. Donnelly. 1974. Demonstration test of inwoods pulp chip production in the four corners region. USDA For. Serv. Res. Pap. RM-125, 18 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Pulpwood and nonmerchantable material were chipped in the woods by a portable debarker-chipper. Two test areas were harvested: a ponderosa pine site in Arizona and a spruce-fir site in Colorado. At the pine site, both saw logs and pulpwood were harvested; saw logs were trucked to a sawmill, but sawtimber tops and pulpwood trees were debarked and chipped in the woods. Harvesting at the spruce-fir site was a thinning of pulpwood-size material following a sawtimber harvest. Sound dead timber was chipped along with thinnings. Chips from both areas were delivered to a pulpmill at Snowflake, Arizona. Feasibility analysis included physical, economic, and environmental evaluation of the inwoods debarking-chipping system as compared with conventional roundwood harvesting.

Oxford: 66:67:311:861.0. **Keywords:** Chipping machines, pulp chips, pulpwood logs, logging operations.

APPENDIX

Table 4. — Man and machine rates used in computing costs

Function	Rate Used
Falling, limbing and bucking	Arizona costs are based on Southwest Forest Industries, Inc. records. $7.00 per hour for chain-saw and operator for Colorado.
Skidding	Arizona costs are based on Southwest Forest Industries, Inc. records. $17.10 per hour for skidder, operator, and choker setter on the spruce-fir area in Colorado; $17.96 per hour for reskidder and operator
Loading pulpwood	$37.03 per hour for loader man, operator, and assistant loader man.
Hauling pulpwood	$0.12 per loaded mile per unit
Rail haul	Contract rate of $3.53 per unit, McNary to Snowflake
Slashing	$7.12 per unit based on past records
Chipping	$53.84 per hour for inwoods debarker-chipper, operator and helper $17.68 per hour for front-end loader and operator $3.20 per unit for chipping at the mill based on past records
Truck haul chips	Rates computed
Rail haul chips	Contract rate of $7.89 per unit, Gallup, N.M. to Snowflake
Reload chips on rail	$0.40 per unit estimate
Scaling and reloading chips at mill	$0.40 per unit
Scaling, unloading pulpwood at mill	$0.75 per unit

Specifications and Features of the "Logger" Model Utilizer

General Characteristics

The Utilizer consists of two units, each of which has a standard fifth-wheel hookup for a highway tractor. Both units are of legal highway size and weight. The two units couple together for the debarking-chipping operation, and can be moved coupled together off the highway where roads are relatively straight. Maximum log diameter that can be processed is 18 inches. Minimum diameter that can be debarked is about 3 inches. Any length from 6 feet to tree length can be handled. Logs shorter than 6 feet generally will not feed through the tandem hold downs on the debarker.

Specifications

Loader: Nicholson hydraulic heel boom, with cab equipped for complete plant control, except for circuit-breaker panel.

Debarker: Nicholson design 18-inch ring debarker, fully automatic, supplied with tandem hold-down rolls controlled by photo-electric cells. A Nicholson 18-inch-wide belt conveyor can discharge bark to either side of the machine.

Chipper: Nicholson 18-inch V drum overhead-discharge 6-knife model.

Table 5. — Cost determinations for the Nicholson "Logger" Model Utilizer

Investment Estimate	
Logger Utilizer	$200,000.00
Freight (Seattle to Springerville)	2,896.00
Spare Parts Inventory	4,000.00
Local Taxes	7,140.00
Total	$214,036.00

Fixed Costs	
Materials	
Service Truck ($6,000÷6)	$1,000.00
Tools ($3,300÷6)	550.00
Other	
Office (supplies, phone, etc.)	350.00
Insurance (1% of average value)	1,000.00
Taxes (200,000 x .25 @ $6.3294 per $100)	3,165.00
Depreciation	35,673.00
Interest (6% add on for initial investment)	12,842.00
Pre-startup and training ($1,200÷6)	200.00
Total Fixed Cost/Year	$54,780.00
Fixed Costs/Hour (Total÷1600 hrs.)	$34.24

Variable Costs	
Labor — Operating (42 weeks x 40 hours/week)	
Operator ($5.53/hour x 1680)	$ 9,290.00
Helper ($4.13/hour x 1680)	6,938.00
Labor — Maintenance (9 hours/week performed by both operator and helper at 1½ times normal rate)	5,216.00
Parts and Supplies	
Equipment ($0.25/unit x 63 units/day x 200 days)	3,150.00
Diesel Engines ($0.60/hour x 1600 hours)	960.00
Diesel Fuel (14.5 gals/hr. at $0.25/gal. — machine running time/day x 14.5 x $0.25 x 200)	5,800.00
Total Variable Costs/Year	$31,354.00
Variable Cost/Hour (Total÷1600 hrs.)	$19.60

Total Utilizer Costs	
Owning Cost/Hour	$34.24
Variable Operating Cost/Hour	19.60
Total Utilizer Cost/Hour	$53.84
Front-end Loader	
Owning Cost/Hour	$ 6.78
Variable Operating Cost/Hour	10.90
Total Loader Cost/Hour	$ 17.68
Total Hourly Cost of Operating Utilizer System	71.52
Total Cost of Operating Utilizer System/8-hour Day	572.16

Feed Rate: Feed rate is 115 feet per minute for ⅞-inch chips, 100 feet per minute for ¾-inch chips, and 85 feet per minute for ⅝-inch chips.

Engines: A Cummins 903 Diesel with a Clark 16.1 torque converter was used in the field test to power the chipper and log feed. A Caterpillar D330 Diesel Generator Set provided electric power for all other functions. Diesel fuel consumption for both engines is about 14.5 gallons per hour.

Length and Weight of Units: The unit containing the generator set and loader is 8 feet wide, 40 feet long, 13.5 feet high, and weighs approximately 40,000 pounds. The debarking-chipping unit is 8 feet wide, 34 feet long, 13.5 feet high, and weighs approximately 45,000 pounds. With units coupled together, overall length is about 70 feet.